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Making MANPRINT Count in the Acquisition Process

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The Manpower and Personnel Integration (MANPRINT) program is a comprehensive management and technical effort that focuses on the continuous integration of the six MANPRINT domains (Human factors engineering, manpower, personnel, training, system safety, and health hazards) into the Materiel Acquisition and Development Process (MADP). In this report, the implementation of MANPRINT during the acquisition of the Airborne Target Handover System/Avionics Integration (ATHS/AI) for the Apache (AH-64A) aircraft is described, and the contribution of MANPRINT concepts to the definition of the system's performance requirements is detailed. Researchers concluded that using MANPRINT concepts in the acquisition of the ATHS/AI for the AH-64A helped to define a system that should reduce crew task times, number of crew procedures, and maintenance complexity.

As a historical overview of the procurement of the ATHS/AI for the AH-64A, the report describes how MANPRINT issues influenced the initial Product Improvement Program (PIP) and (Continued)

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the Engineering Change Proposal (ECP) and describes how MANPRINT concepts were conveyed in the Request for Proposal (RFP). The application of MANPRINT in the Source Selection Process (SSP) is described and the lessons learned from this experience are summarized. These lessons are strategies that are potentially useful to other MANPRINT practitioners.

MAKING MANPRINT COUNT IN THE ACQUISITION PROCESS

CONTENTS

LIST OF TABLES

MAKING MANPRINT COUNT IN THE ACQUISITION PROCESS

INTRODUCTION

The Manpower and Personnel Integration (MANPRINT) Program is a comprehensive management and technical effort to assure total system effectiveness by focusing on the continuous integration of all relevant information from the six MANPRINT domains (human factors engineering, manpower, personnel, training, system safety, and health hazards) into the Materiel Acquisition and Development Process (MADP) (Army Regulation 602-2, 1987). An ultimate goal of the MANPRINT program is to improve soldier performance. When successfully addressed in the MADP, MANPRINT promotes also the development of weapon systems that have lower operational and support costs and improved battlefield effectiveness. The integration of the six MANPRINT domains into the MADP has recently become a directed responsibility of the entire Army research and development community (Army Regulation 602-2, 1987).

However, there have been struggles to see that MANPRINT is addressed in a meaningful manner in the MADP and is not just a new name for an old concern that does not change the way systems are procured and developed. As a result of the World War II experience, it was recognized that operator performance, which is determined to a large extent by the total man-machine interface, affects system performance and mission effectiveness. Initially, efforts to address man-machine interface issues focused on the man-hardware interaction, concerned primarily with controls and displays. Over the years, and stimulated more recently by the mandate of the MANPRINT program, the integration of man-machine interface issues in system procurement and development has been expanded to encompass a broad range of human performance considerations, e.g., the cognitive and manual workload imposed on the operator and maintainer by the software and hardware design, and the conformance of system operational and maintenance requirements with the capabilities and limitations of the fully equipped soldier.

The Airborne Target Handover System/Avionics Integration (ATHS/AI) onto the Apache (AH-64A) aircraft is an acquisition program that shows how MANPRINT can be implemented in the MADP and how MANPRINT concepts can contribute to the definition of total system performance requirements. In the context of a historical overview of the procurement of the AH-64A/ATHS-AI, this report describes how MANPRINT concepts influenced the procurement process and were conveyed in the Request for Proposal (RFP), and describes the application of MANPRINT in the Source Selection Process (SSP). The lessons learned from the AH-64A experience are summaried. These lessons are strategies that are potentially useful to other MANPRINT practitioners for implementing MANPRINT concepts in the MADP.

Overview of the Apache (AH-64A)

The AH-64A was developed in the early 1980's when system growth in capability and demands on personnel were often in conflict. The adverse effects of expanded system capabilities on crew workload were human factors deficiencies in the design of the AH-64A crew-system interface, and the interface hindered the full employment of the aircraft's capabilities. For example, as new sensor data flowed into the cockpit, the crew had to assume the role of system integrator, in addition to their primary duty of piloting the aircraft and firing the gun. Also, the crew's ability to effectively employ the Apache's capabilities were hampered by the increased operator workload caused by the full range of 51 possible combinations of employing the fire control system. In 1984, it was acknowledged that the integration of the ATHS onto the AH-64A could enhance the crew-system interface to reduce crew workload and provide other capabilities to the crew to increase mission effectiveness.

Overview of the Airborne Target Handover System/Avionics Integration (ATHS/AI)

Operationally, the integration of ATHS/AI onto the AH-64A is intended to provide improved crew coordination, control, communication, efficiency and reduced crew workload. An additional prime operational objective is to increase the mission effectiveness of the AH-64A by providing functions to transfer mission data between ground, air and command elements.

The ATHS/AI is a fully-integrated, multiplexed avionics system for the AH-64A that will give the crew centralized control of the communications, navigation and identification equipment in the crew station. In addition, the ATHS/AI will provide expanded communications capabilities with the SINCGARS enhanced communications security and fixed-formatted, digital burst communications, and other enhancements. A new avionics data bus will be added to the aircraft for avionics equipment control and future avionics growth potential. Digital burst communications for HELLFIRE and other type messages are intended to enhance target handover between the AH-64A aircraft and the OH-58D aircraft, between the AH-64A aircraft and ground based designation units for remote HELLFIRE launches, and to provide a digital burst communication for transmitting and receiving pre-formatted field artillery messages through TACFIRE units (Department of the Army, 1987, July).

MANPRINT IN THE ATHS/AI AH-64A ACQUISITION PROCESS

The ATHS/AI procurement for the AH-64A aircraft extended from December 1984 to April 1988, the date of contract award. Some of the highlights of the ATHS/AI procurement are described,

emphasizing the role of MANPRINT issues as major drivers in the acquisition process.

Product Improvement Program

The original ATHS Product Improvement Program (PIP) was generated in December 1984. In May 1985, the Aviation Center at Fort Rucker supported the concept of a fully integrated approach. i.e., the ATHS/AI. In August 1985, the Vice Chief of Staff of the Army directed that the ATHS be put onto the APACHE. Eighteen Apaches at Fort Hood and six Apaches at Fort Rucker were initially targeted for modification to be used for initial training and field operational validation. However, the ATHS was first installed onto the AH-64A in early 1986 to support the Operational Test (OT II) of the OH-58D scout helicopter, conducted at Fort Hunter-Liggett, California. These tests raised concerns over the lack of sufficient crew training and total mission equipment integration of the ATHS, which prevented a complete demonstration of the ATHS operational effectiveness.

Initial ATHS Installation onto the AH-64A: The basic ATHS system, initially installed onto the AH-64A, consisted of the Primary Display unit (CMS-80) and the Processor Interface Unit (PIU). The CMS-80 consisted of the Control Display Unit (CDU) and the Collins keyboard. The CDU provided the direct crew manual interface with the ATHS system and the PIU processed the data from the aircraft data base with an interface to the communication equipment to transmit and receive the digital data messages.

The initial units that were installed onto the AH-64A in 1986 were add-on systems to the copilot and gunner position in the front seat position only. The system was basically a stand alone unit that was only partially integrated with the MIL-STD-1553B (1986) data bus to permit communication with part of the AH-64A systems, excluding the fire control functions. This configuration added yet another system for the copilot and gunner to interact with as the system integrator, giving the operators a third keyboard. (The basic AH-64A already had two different keyboards in the front seat.)

Engineering Change Proposal

In December 1986, Engineering Change Proposal 801 (ECP) was submitted by the APACHE prime contractor, McDonnell Douglas Helicopter Company, to accomplish the ATHS modification. In January 1987, the results of a Users' Conference indicated that the ECP lacked effective crew-system integration to meet the operational requirements, and work was stopped on ECP 801.

Request for Proposal: Modification Work Order Retrofit

A draft competitive Request for Proposal (RFP) was issued in May 1987 for installing the ATHS/AI onto the AH-64A as a Modification Work Order (MWO) retrofit. This draft RFP lacked a specific definition of the system operational objectives pertaining to mission accomplishment. As such, the draft version continued the obvious shortcoming of the ATHS application in the AH-64A that existed with the initial ECP; specifically, the draft RFP lacked effective man-machine integration to reduce crew mission time lines and associated operator workload.

Recognizing the shortcoming of the draft RFP, the Army Aviation Systems Command (AVSCOM) requested that the Army Research Institute for the Behavioral and Social Sciences (ARI) prepare the statements of work and specification requirements for the final RFP (Department of the Army 1987, August). The revisions to the RFP required an effective response from the offerors in their proposals that would help insure the operational suitability requirements of the system would be thoroughly addressed and integrated. The final RFP was expanded to include the needed system integration requirements and released to industry in August 1987.

An ATHS/AI AH-64A Comparative Time Line Analysis developed by ARI was provided as Attachment 16 to the final RFP. The function of this attachment to the RFP was to provide to industry a baseline crew task time for selected mission functions judged by subject matter experts (AH-64A pilots, gunners and instructor pilots) and human factors engineers to be potentially most affected by the integration of the ATHS onto the AH-64A (See Table 1, a summary of the baseline time lines reported in the RFP). This baseline data was important, as it gave each offeror the same foundation from which to define the magnitude of their proposed improvements for the integration effort. Also, by accomplishing this work, the Army was able to predict where the greatest improvement could be achieved and the corresponding impact on mission effectiveness.

Such an effort was in direct response to the Army MANPRINT program requirement. The "Purpose" paragraph of Army Regulation 602-2 reads, in part:

> This regulation.......emphasizes front-end planning of soldier-materiel system design for optimum total system performance as part of the Army materiel systems acquisition process (p.3).

The culminating step was to place within the system specification the requirement for the offeror to achieve a 30 percent reduction in crew task time for each task with a goal of achieving a 60 percent reduction. This was to be achieved with a 98 percent mission reliability and with no more than 5 percent of the mission aborts attributed to human errors (See Table 2, an offeror's time line analysis plan).

Table 1

Summary of Baseline Time Lines for AH-64A Mission Functions Affected by ATHS Integration

Function	Baseline Time Lines (Seconds)
Acquire Target (DTV)	43
Acquire Target (DVO)	39
Acquire Target (FLIR)	47
*Enter Fire Control Data	740.5
*Enter Target Data	30.5[a]
Perform After Starting APU Check (Gunner)	36
Perform After Starting APU Check (Pilot)	148.5
Perform Aircraft Position Update	47.5
Perform ATHS Operational Check (Gunner)[b]	0
Perform ATHS Operational Check (Pilot)[b]	0
Perform External Communication (Authored)	28[c]
Perform External Communication (Freetext)	28[d]
Perform External Communication (Movement A)	28[e]
Perform External Communication (Movement B)	28[f]
Perform Navigation[g]	
Prepare Performance Planning Card[h]	334
*Program Doppler	101[i]
Receive Cockpit Communication[j]	7
*Receive External Communication	22[k]
*Receive Handover	29.5
Select Weapon, Gun (Gunner)	20.5
*Select Weapon, Missile	16.5
*Select Weapon, Missile (Remote Designation)	15
Transmit Cockpit Communication	7
Transmit Message (Attack Coordination)	21
Update Doppler (Landmark)	268
Update Doppler (Stored Destination)	50.5

Note. The symbol "*" denotes mission functions of primary importance.

Table 1 continued

Summary of Baseline Time Lines for AH-64A Mission Functions Affected by ATHS Integration

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[a] Represents time required to enter and check coordinates for one target.

[b] Represents a new function not included in the baseline analysis.

[c] Represents time required to send a preset message.

[d] Represents time required to prepare and send a freetext message.

[e] Represents time required to send a preset movement message.

[f] Represents time required to prepare and send a movement message.

[g] A continuous function whose length varies with the specific segment in which it occurs. ATHS affects the length of specific tasks that occur randomly during the function.

[h] Includes all items on the Performance Planning Card, not just the mandatory items.

[i] Represents time required to enter and check coordinates for one waypoint.

[j] ATHS will not affect the length of this function, but will reduce the number of times required to perform the function during the mission.

[k] Based on handover of one target.

Table 2

Collins Government Avionics Division's Time Line Analysis Plan

Function	Time Line Goals (Seconds) Baseline	Required	Desired
Acquire Target (DTV)	43	30.1	15.0 - 18.0
Acquire Target (DVO)	39	27.3	15.0 - 18.0
Acquire Target (FLIR)	47	32.9	15.0 - 18.0
Enter Fire Control Data	740.5	518.4	32.5 - 43.5
Enter Target Data	30.5	21.4	15
Perform After Starting APU Check (Gunner)	36 (18)	25.6	23.0 - 27.0
Perform After Starting APU Check (Gunner)	148.5 (39.5)	103.9	117.5 -123.5
Perform Aircraft Position Update	47.5 (28)	33.3	25
Perform ATHS Operational Check (Gunner)	NA	NA	10
Perform ATHS Operational Check (Pilot)	NA	NA	10
Perform Authored External Communication	28	19.6	11.5
Perform Freetext External Communication	28	19.6	19
Perform Movement A External Communication	28	19.6	11.5
Perform Movement B External Communication	28	19.6	18.5
Prepare Performance Planning Card	334	233.8	OFF AC
Program Doppler	101	70.7	4.0 - 8.5
Receive Cockpit Communication	7	4.9	AUTO
Receive External Communication	22	15.4	5
Receive Handover	29.5	20.7	8

Collins Government Avionics Division's Time Line Analysis Plan

	Timeline Goals (Seconds)		
Function	Baseline	Required	Desired
Select Weapon, Gun (Gunner)	20.5 (10.5)	14.4	12.5
Select Weapon, Missile	16.5	11.6	AUTO
Select Weapon, Missile (Remote Designation)	15	10.5	AUTO
Transmit Cockpit Communication	7	4.9	AUTO
Transmit Message (Attack Coordination)	21	14.7	1
Update Doppler (Landmark)	268 (25.5)	187.6	255
Update Doppler (Stored Destination)	50.5 (5)	35.4	47.5

Note. From Rockwell International, Collins Government Avionics Division, 29 April 1988 Briefing. Cedar Rapids, IA. Numbers in parentheses are based on the steps which are specific to the ATHS/AI requirements. Numbers separated by a hyphen define a desired range.

MANPRINT IN THE ATHS/AI AH-64A SOURCE SELECTION PROCESS

Structure of the Source Selection Advisory Council (SSAC)

The SSAC for the ATHS/AI AH-64A provided equal weight to the technical area and the MANPRINT and operational suitability area. This assignment was a direct consequence of the fact that MANPRINT concerns were effectively incorporated into the RFP system specifications. The MANPRINT weight is also explained by the placement of MANPRINT practitioners in positions of authority in the source selection organizational structure, e.g., a MANPRINT practitioner served as Source Selection Evaluation Board (SSEB) MANPRINT and Operational Suitability Area Chief.

Thus, for the first time in aviation procurement, the statement was made to industry that for this ATHS/AI AH-64A modification the Army considered the operational and maintenance aspects concerning the man-machine interface of equal importance to the technical issues of performance, weight, etc. In reality, as the contractor improved the soldier interface, the technical and supportability configuration also improved. Accordingly, the technical and MANPRINT issues were found to be interdependent, and planned improvements in system integration should result in an improved weapon system from the viewpoint of several areas.

The other areas of the board were cost, logistics, and management. None of these areas was scored quantitatively, but all were evaluated as having met their respective requirements. Cost was evaluated on its own merit and was considered the single most important area.

User Involvment

The involvement of APACHE pilots, maintainers, and instructors in the preparation of the RFP and in the actual Source Selection Process (SSP) aided immeasurably in defining with authority the crew-system interface issue. The contractor representatives quickly realized that this contract would not be won on the basis of vague phrases only (e.g., "reduced pilot workload" and "lower mean time between failure"). Instead, the contractors used definitive statements of system performance that permitted the user to make a direct assessment of the impact of proposed system characteristics on mission effectiveness, such as:

> ...The ATHS/AI modified AH-64A shall allow missile launch in an average of less than 10 seconds (current average time is 28 seconds) from the time of ATHS mission acceptance....The allowable time shall exclude the time required to "spin up" the missile and bring the aircraft into launch constraints...." (Rockwell International, 1988, p. 11).

The individual crew tasks times used in the evaluation process further illustrate the depth of the evaluation that was accomplished. In addition to the 27 different mission function time lines (See Table 1), the RFP also contained the time lines for the individual crew tasks that makeup each mission function. Using these data, the offerors were able to determine how the government was establishing the baseline task and workload analysis for the AH-64A. Each offeror then responded with how they intended to reduce both the mission function time lines and the crew task time lines. (See Table 2, an offeror's time line analysis plan for mission functions). The crew tasks were evaluated for the potential for human error and increased crew workload. For example, each defined task received critical evaluation by the AH-64A instructor pilots participating on the SSEB for the number of task steps, the level of automation, and the degree of flexibility the crew would have to tailor the system "on the fly" from one mission objective to another.

Critical Discriminators

As the board's evaluation progressed, the users and other members were able to identify the key discriminators that permitted a scaling of the offerors' proposals. One of the major discriminators was the level of system integration that was being offered. It was difficult to assess why all of the offerors were not providing essentially the same level of integration. Were they unaware of the need for system integration to affect pilot workload; were they uninformed as to the capability of the AH-64A architecture and the potential benefits to be achieved through the ATHS integration; or were they holding back for costly ECP potential or some other corporate management strategy? Nonetheless, the level of integration of the ATHS with the Apache's fire control, navigation, and communication system became a prime discriminator. The impact on mission accomplishment was directly related to the degree of integration provided. If the integration was not present, it represented additional crew workload (manual and cognitive), which may have adverse effects on task times, system safety, and human error.

Another discriminator was the attention paid to the maintainer. Issues were raised such as the removal of the old, unused wiring that would be left over after modification. The potential adverse impact on fault isolation or battle damage repair of a system with potentially over 100 "dead" wires was obviously unacceptable to the user. Another maintenance concern was the location and accessibility of Line Replaceable Units (LRU). Also, questions concerning the need to remove one item to get to another, use of blind fasteners, and access with arctic gloves or nuclear, biological, and chemical (NBC) protective gloves were asked of each offeror.

The response by some of the offerors to the maintainer inquiries was that their design configurations were not

developed in sufficient detail to address operational maintainer concerns. Although the absence of a detailed configuration was an acceptable response, these contractors also were unwilling to place statements in their contractual commitment volumes that would require them to address the maintainer issues in their final designs. Thus, those offerors who had accomplished sufficient work to describe their configuration and make commitments to meet Army maintainer requirements were evaluated as having a better proposal with lower risk of achieving the MANPRINT objectives.

The area of MANPRINT management was another critical discriminator. If the contractor had proposed a good design, he must also have had an effective corporate management structure that would permit the execution of the MANPRINT program throughout system development. However, some of the offerors' proposals reflected basically "the business as usual approach"; specifically, each of the individual MANPRINT corporate groups (e.g., Human Factors, Safety, Integrated Logistics, and Training) would operate autonomously and unconstrained by a MANPRINT manager, whose office was established to satisfy Army requirements only.

Other offerors placed the MANPRINT Manager as a separate position reporting directly to the project manager, with responsibility to direct and coordinate the activity of the six domains of MANPRINT and interface on an equal level with the engineering and integrated logistics community. This management structure was evaluated as having the lowest risk of achieving the MANPRINT objectives, since the MANPRINT manager was given the corporate position, responsibility and authority to execute the MANPRINT program.

Supportive of the MANPRINT management was the schedule of activity relating to key milestones that would enable the MANPRINT tools, analysis, validation, and demonstrations to be applied to the development of the ATHS/AI in a proactive, effective manner. Again, if an offeror proposed a schedule that had the initial human factors mission and functional analysis being completed after the preliminary design review, it was hard to rationalize the impact that this effort would have on formulating the soldier requirements for the crew station configuration, or the software structure. It appeared that the offerors were saying, "We will do the analysis, because the Army has required it to be accomplished; but it will be done off-line, and not used to address configuration issues."

Choosing the Winner on MANPRINT Grounds

What made Rockwell-Collins the winner from a MANPRINT and operational suitability perspective? It was clear that this offeror was not "paying lip service" to the operational requirements placed in the RFP. The offeror was making a concerted effort to reduce crew workload through improved ATHS integration. In the Collins design, the ATHS fully assumed the role of

operator. For example, the ATHS functioned as the system integrator for presetting, changing, and prioritizing the fire control, navigation, and communication systems and performed other integration functions between subsystems.

Integration was accomplished in such a manner as to retain the crew's necessary options for manual control if required by the mission; and, in addition, the integration permitted the copilot and pilot to operate simultaneously in different modes (autonomous and non-autonomous). For example, if the copilot is losing a target, the system permits him to fire on that target independent of control by the ATHS (autonomous), while the pilot accepts an ATHS mission for a remote designated Hellfire launch at another target (non-autonomous). The missile launch can be accomplished by the pilot pushing one key after accepting the ATHS/AI mission. Substantially decreasing the pilots workload, the Rockwell-Collins proposed ATHS selects the appropriate missile type, missile mode, firing trajectory, missile channel, missile seeker laser code, and missile quantity, and will prioritize the appropriate channel for the first missile launch. In addition, either crew member can access and review an ATHS message and initiate a selected automated TADS or Hellfire function while the other crew member is simultaneously formatting an ATHS message (Rockwell International, 1988). As shown by these examples, the AH-64A crew with the ATHS/AI system integrated as described in the winning proposal does more than just send messages by data burst.

SUMMARY

The application of MANPRINT concepts in the acquisition of the ATHS/AI for the AH-64A aircraft assisted in defining a system that should reduce crew task times, the number of crew procedures and maintenance complexity. Clearly the early involvement of the user in the definition of the system and in the Source Selection Process (SSP) had a significant impact on the ATHS integration onto the AH-64A. Contractors who can successfully grasp the potential impact of MANPRINT on their product will not see MANPRINT activities as increasing costs, but will see MANPRINT activities as a means of avoiding costs. MANPRINT is cost effective during the early stages of the MADP, because its implementation supports the improved definition of the man-machine interface and total requirement up-front, when schedule, costs, and materials are less impacted by design definition interactions. The investment of MANPRINT resources, personnel and technology, during the acquisition phase will reap the projected rewards of improved weapon systems for the Army.

Additional lessons learned from implementing the MANPRINT program during the acquisition phase of the ATHS/AI AH-64A are summarized below. These lessons learned are strategies that potentially can be used by other MANPRINT practitioners.

1. MANPRINT practitioners should establish viable working relationships with Army personnel from the offices of the program, project, or product manager, the Training and Doctrine Command (TRADOC) system manager, and the training developer, or with other key participants in the MADP. Contact with key Army personnel will increase the visibility and use of MANPRINT technology and will provide a communication mechanism for practitioners to influence the decision making process.

2. MANPRINT concerns must be effectively incorporated into the system specifications, and quantitative input should be provided whenever possible to do so (e.g., the baseline time lines for the AH-64A functions and the system performance requirement, a 30% reduction in the baseline time lines). The quantitative data contained in the system specifications provide objective measures that the Army can use to determine if its requirements have been satisfied. Also, the quantitative data have utility throughout the MADP (e.g., in the Source Selection Process, the monitoring and assessment of contractor performance during system development and the operational test).

3. MANPRINT practitioners should establish viable working relationships with users. The user community is an invaluable resource for data and is instrumental to the success of the MANPRINT program.

4. As appropriate, MANPRINT practitioners should assure that the MANPRINT human performance issues are not restricted to operator concerns. For example, operator concerns frequently predominate the MANPRINT issues, and significant maintainer concerns are omitted. As indicated, MANPRINT issues should include human performance considerations that concern the military, civilian and contract personnel who will operate, maintain and support the system.

5. MANPRINT personnel should make certain that the evaluation of the offerors' proposals is thorough. The offerors' corporate management structures for implementing the MANPRINT program and the MANPRINT schedules should be assessed.

6. The continued involvement of government MANPRINT personnel throughout the development cycle, operational test and fielding of the system is also critical. For example, participation in the Test Integration Working Group (TIWG) is necessary to ensure that the MANPRINT issues in the RFP are incorporated in the Test Evaluation Master Plan (TEMP). Participation in critical design reviews, mockups and other contractor demonstrations are impo tant for monitoring contractor implementation of the MANPRINT program and promotes viable working relationship between Army MANPRINT personnel and contractor MANPRINT personnel. In addition, contact with contractor personnel helps remove attitudinal barriers that adversely effect the implementation of the MANPRINT program.

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